The Audible Pop from Thoracic Spine Thrust Manipulation and Its Relation to Short-Term Outcomes in Patients with Neck Pain

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Abstract: Clinicians routinely consider the success of a thrust manipulation technique based on the presence or absence of an audible pop despite the lack of evidence suggesting that this pop is associated with improved outcomes. The purpose of this study was to determine the relationship between the number of audible pops with thoracic spinal manipulation and improvement in pain and function in patients with mechanical neck pain. In this prospective cohort study, 78 patients referred to physical therapy with mechanical neck pain underwent a standardized examination and thoracic spine manipulation treatment protocol. All patients were treated with a total of 6 thrust manipulation techniques directed to the thoracic spine followed by a basic cervical range of motion exercise. The treating clinician recorded the presence or absence of a pop during each manipulation. Outcomes were assessed at a 2-4 day follow-up with an 11-point numeric pain rating (NPRS), the Neck Disability Index, the patient Global Rating of Change (GROC), and measurements of cervical range of motion (CROM). The relationship between the number of pops and change scores for pain, disability, and CROM was first examined using Pearson correlation coefficients. Individuals were then categorized as having received ≤3 or >3 pops. Repeated measures analyses of variance were used to examine whether achievement of >3 pops resulted in improved outcome. Seventy-eight patients with a mean age of 42 (SD 11.3) years participated in the study. Pearson correlation coefficients revealed no significant correlation existed between the number of pops and outcomes with the exception of 3 of the 6 CROM measurements, which were inversely related. There was no significant interaction for group X time for any of the dependent measures ($P>0.05$). The odds ratio for patients experiencing dramatic improvement was in favor of the group experiencing ≤3 pops but this was not clinically meaningful (1.3: 95% CI 0.46, 3.7). The results of this analysis provide preliminary evidence for the hypothesis that there is no relationship between the number of audible pops during thoracic spine thrust manipulation and clinically meaningful improvements in pain, disability, or CROM in patients with mechanical neck pain. Additionally, a greater number of audible pops experienced was not associated with a dramatic improvement with manipulation treatment.

Key Words: Cavitation, Manipulation, Neck Pain, Audible Pop, Thoracic Spine

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The prevalence of neck pain is high, with nearly 70% of individuals experiencing neck pain at some point in their life and with 15-22% of individuals continuing to experience symptoms 5 years after onset[1,2]. This results in a substantial economic burden as nearly 1/3 of patients who experience a first-time onset of neck pain will report continued healthcare utilization for their neck pain at a 10-year follow-up[3]. Additionally, nearly 25% of all visits in outpatient physical therapy practice consists of patients with a primary report of neck pain[4].

Physical therapists utilize a number of interventions in the management of neck pain including joint manipulation (non-thrust and thrust), therapeutic exercise, traction, and a variety of modalities[5]. Recently, evidence has begun to emerge for the use of manual therapy, specifically thrust procedures, directed to the thoracic spine in patients with mechanical neck pain[6-9]. Clinicians often believe that an audible pop associated with a thrust manipulation is a criterion for determining the success of the technique[10]. However, ultimately the success of an intervention should be based on whether it is associated with improvements in patient-centered outcomes[11].

Recently Flynn, Fritz, et al[12] reported on a series of 71 patients with non-radicular low back pain (LBP) who received lumbopelvic thrust manipulation. Participants underwent a standardized examination and standardized spinal manipulation treatment program. All patients were treated with a sacroiliac region manipulative technique, and the presence or absence of an audible pop was noted. Similar to the operational definition of an audible pop used in this study, the number of actual pops that may have occurred during one thrust manipulation was not recorded but only whether an audible sound was perceived during one particular manipulation. The subjects were reassessed 48 hours after the manipulation for changes in range of motion (ROM), in pain as measured by the Numeric Pain Rating Scale (NPRS), and in Oswestry (OSW) scores. There were no between-group differences for flexion ROM, NPRS, and OSW scores ($P>0.05$). The odds ratio (1.2; 95% CI: 0.38-4.04) suggested that the occurrence of a manipulative pop would not improve the odds of achieving a dramatic reduction in symptoms following the manipulation[12]. Based on the data, the authors concluded that there was no relationship between an audible pop during sacroiliac region manipulation and improvement in ROM, pain, or disability in individuals with non-radicular low back pain[12].

In a follow-up study, Flynn, Childs, et al[13] examined whether the occurrence of a manipulative pop during lumbopelvic region manipulation was related to the outcome of the intervention over a 4-week period of time rather than the 48-hour follow-up in the earlier study. Seventy patients were randomly assigned to receive thrust manipulation during the first two sessions. Therapists recorded whether the patient or therapist heard either a single or multiple audible pops. Again similar to the operational definition of an audible pop used in this study, the number of actual pops that may have occurred during one thrust manipulation was not recorded. Outcome was assessed with an 11-point NPRS, the OSW, and measurement of lumbopelvic flexion ROM. No differences were detected at baseline or at any follow-up period in the level of pain, the OSW score, or lumbopelvic ROM based on whether a pop was achieved ($P>0.05$). The odds ratios and 95% confidence intervals for achieving a successful outcome at each of the follow-up periods all approximated a value of 1, suggesting no improvement in the odds of successful outcome among patients in whom an audible pop occurred. The results supported the previous findings that the audible pop was unrelated to changes in patient-centered outcomes for patients with LBP[13].

While previous studies provide evidence that an audible pop accompanying lumbopelvic thrust manipulation is not associated with improved patient-centered outcomes, this has yet to be examined in other spinal regions. Therefore, the purpose of this study was to examine the relationship between the audible pop and patient-centered outcomes in a cohort of patients with neck pain treated with thoracic spine thrust manipulation.

Materials and Methods

Data collected during a prospective cohort study of patients with mechanical neck pain referred to physical therapy at Rehabilitation Services of Concord Hospital, Concord, NH, were used for this analysis[7]. Inclusion criteria required patients to be between the ages of 18 and 60 years, with a primary complaint of neck pain with or without unilateral upper extremity symptoms, and a baseline Neck Disability Index (NDI) score of 10% or greater. Exclusion criteria were identification of any medical red flags suggestive of a non-musculoskeletal etiology of symptoms, history of a whiplash injury within 6 weeks of the examination, a diagnosis of cervical spinal stenosis, evidence of any central nervous system involvement, or signs consistent with nerve root compression (at least two of the following had to be diminished to be considered nerve root involvement: myotomal strength, sensation, or reflexes). All patients reviewed and signed a consent form approved by the Institutional Review Board at Concord Hospital.

Therapists

Four physical therapists participated in the examination and treatment of patients in this study. All therapists underwent a standardized training regimen, which included studying a manual of standard procedures with operational definitions and video clips demonstrating each examination and treatment procedure used in this study. All participating therapists then underwent a 1-hour training session in which they practiced the examination and treatment techniques to ensure that all study procedures were performed in a standardized fashion. Prior to participating in data collection, therapists were visually observed by one of the investigators as being able to successfully perform all examination and treatment procedures on a patient with neck pain. Participating therapists had a mean of 12.3 years (SD 10.0, range 3–23 years) of clinical experience.

Examination

All patients provided demographic information and completed a number of self-report measures, followed by a standardized history and physical examination at baseline. Self-report measures included a body diagram[14], the NPRS[15], the NDI[16], and the Fear-Avoidance Beliefs Questionnaire (FABQ)[17].

Self-Report Measures

Fear Avoidance Beliefs Questionnaire. The FABQ was used to quantify the patient's fear avoidance beliefs about physical activity as well as work[17]. The FABQ consists of a work (FABQW) and physical activity (FABQPA) subscale, both of which have been shown to exhibit a high level of test-retest reliability[18]. The FABQW subscale has been shown to exhibit predictive validity in the identification of patients with LBP who are likely to respond to spinal manipulation[19,20], but the predictive validity for patients with neck pain with regard to a positive response to the regimen discussed in this study is unknown. In this study, the FABQ was modified by replacing the word "back" with "neck," as has been done in other studies[7,21].

Neck Disability Index. The NDI contains 10 items, 7 related to activities of daily living, 2 related to pain, and 1 related to concentration[22]. Each item is scored from 0-5 and the total score is expressed as a percentage, with higher scores corresponding to greater disability. The NDI has been demonstrated to be a reliable and valid outcome measure for patients with neck pain[23-25], and it has been widely used in clinical trials of patients with neck pain[16,26-28]. Westaway[29] identified the minimal detectable change (MDC) on the NDI as 5 points as did Stratford et al[25] in a group of patients with neck pain. Both of these studies reported the MDC on a 50-point scale; because we calculated the NDI as a percentage out of 100, this translates to an MDC of 10 percentage points. Although these studies reported that a change of 5 points (or 10 percentage points) must be observed to be certain that the change in scores is greater than measurement error, no values for the minimal clinically important difference (MCID) have been reported in the literature for patients with mechanical neck pain[25,30]. However, the MCID in a patient population with cervical radiculopathy has been demonstrated to be 7 points (or 14 percentage points)[31].

Numeric Pain Rating Scale. The numeric pain rating scale (NPRS) was used to capture the patient's level of pain. Patients were asked to indicate the intensity of current, best, and worst levels of pain over the past 24 hours using an 11-point scale ranging from 0 ("no pain") to 10 ("worst pain imaginable")[32]. The average of the three ratings was used to represent the patient's level of pain over the previous 24 hours. This procedure has been shown to have adequate reliability, validity, and responsiveness in patients with LBP[33,34]. Childs et al[33] reported a 2-point change on the NPRS as the MCID in patients with mechanical low back pain. However, it should be noted that responsiveness for this measure has not been specifically examined in patients with neck pain.

Standardized Physical Examination.

Following completion of the questionnaires, all patients underwent a standardized physical examination. This examination began with a neurological screening examination[35], followed by postural assessment[36]. The operational definitions for postural assessment used in this study were as follows: the patient was identified as having a forward head if the patient's external auditory meatus was anteriorly deviated (anterior to the lumbar spine)[36] and the shoulders were identified as protracted if the acromion was noted to be anteriorly deviated (anterior to the lumbar spine)[36]. The examiners were instructed to identify the contour of the spine for the following groups of segments: C7-T2 (cervicothoracic junction), T3-T5, and T6-T10. Each group was recorded as normal (no deviation), excessive kyphosis, or diminished kyphosis[37]. Excessive kyphosis was defined as an increase in the convexity, and a diminished kyphosis was defined as a flattening of the convexity of the thoracic spine (at each segmental group)[37]. The reliability of this postural assessment has been shown to range from poor to substantial[38].

The clinician then assessed the length[35] and strength[36] of the muscles of the upper quarter and the endurance of the deep neck flexor muscles[39]. Deep neck flexor endurance was assessed in the following fashion[39]: while in supine, the patients were asked to tuck the chin in while slightly flexing the neck and lifting the head approximately 1 inch off the plinth. This position has been shown to maximally activate the deep neck flexor muscles[40]. The length of time the patient was able to hold this position without deviations was recorded in seconds by the examiner. This technique has been shown to exhibit moderate reliability[38].

Spinal segmental mobility was assessed by a variety of methods previously reported in the literature[35,41,42]. The following techniques are described according to the specific segments; however, we acknowledge that these techniques are likely not segment-specific[43,44]. Mobility of the occipito-atlantal joint was performed as described by Flynn, Whitman, et al[35]. The patient was supine and the examiner cradled the occiput with both hands. The head was then rotated 30° toward the side to be tested, and an anterior-to-posterior glide was performed to assess the amount of available motion compared to the contralateral side[35]. Mobility of the atlanto-axial joints was also performed with the patient in supine, as described by Greenman[41]. The examiner passively and maximally flexed the neck followed by passive cervical rotation to one side, then the other. The amount of motion to both sides was compared, and if one side was determined to have less motion, it was considered to be hypomobile[35]. Reliability for these assessment techniques has been shown to range between poor and substantial[38].

Posterior-to-anterior spring testing of middle to lower cervical spine (C2-C7) and upper to middle thoracic spine (T1-T9) was performed with the patient prone and the neck in neutral rotation as described by Maitland[42]. Spring testing was performed centrally over the spinous processes of the vertebrae and was used to assess both segmental mobility and pain provocation. With the elbows extended, the examiner applied a gentle but firm, anteriorly directed pressure on the spinous process (i.e., posterior-to-anterior). The mobility at each segment was judged as normal, hypomobile, or hypermobile[45]. Interpretation of whether a segment was hypomobile or hypermobile was based on the examiner's perception of the mobility at each spinal segment relative to those above and below the tested segment and based on the examiner's experience and perception of normal mobility. In addition, pain provocation at each segment was judged as painful or not painful[42]. The percentage agreement between rater for identifying pain provocation with manual assessment ranges between 18 and 95%[38].

Next, the clinician performed a number of special tests typically performed in the examination of patients with neck pain including the Spurling test[46], Roos test[47], cervical distraction test[22], and the upper limb neurodynamic test[48]. Specific operational definitions for each test and criteria defining a positive test can be found in Table 1.

The physical examination concluded with the therapist measuring cervical range of motion (CROM) and symptom response[49]. Detailed description regarding the methods used to collect CROM measurements can be found in Table 2. Reliability testing of these specific methods of measuring CROM have yielded an $ICC_{2,1}$ = 0.66–0.78[38].

TABLE 1. Operational definitions for special tests used in the study.

Test and Reliability with 95% CI	Performance	Criteria for Positive Test
Spurling A[22] Kappa= .60(.32-.87)	The patient is seated and the neck is passively side-bent towards the symptomatic side. The examiner applies approximately 7 kg of force through the patient's head with a caudally directed force.	Reproduction of the patient's upper extremity symptoms
Neck Distraction Test[22] Kappa = .88 (.64-1.0)	The patient is supine and the examiner grasps under the patient's chin and occiput. The examiner flexes the neck to patient comfort and then applies a distraction force of approximately 14 kg.	Reduction or resolution of the patient's upper extremity symptoms
Upper Limb Neurodynamic Test A[22] Kappa= .76 (.51-1.0)	The patient is supine and the examiner places the patient's upper extremity into 1) scapular depression, 2) shoulder abduction, 3) forearm supination, wrist and finger extension. 4) shoulder external rotation, 5) elbow extension, and 6) contralateral then ipsilateral cervical lateral flexion.	Any of the following constitute a positive test: 1) Symptom reproduction 2) Greater than 10° difference in elbow extension from side to side 3) An increase in symptoms with contralateral cervical side-bending or decrease in symptoms with ipsilateral side-bending
Roos Test[47] Kappa (not reported)	The patient is standing and abducts the arms to 90 degrees with lateral rotation of the shoulder. The patient then opens and closes the hands slowly for 3 minutes.	The test is considered positive if the patient is unable to maintain the position or reports heaviness and tingling in the arm.

CI-confidence interval; kg-kilograms.

Treatment

All patients were treated with the same set of manipulation techniques. Each patient received 3 different thrust manipulation techniques directed to the thoracic spine. The first technique was the “distraction manipulation.” The patient was seated and the therapist placed his/her upper chest at the levels of the middle thoracic spine and grasped the patient’s elbows. A high-velocity distraction thrust was performed in an upward direction (Figure 1). The second technique (upper thoracic spine manipulation) was performed in supine with the patient clasping his/her hands across the base of the neck. The therapist’s manipulative hand was used to stabilize the inferior vertebra of the motion segment and his/her body was used to push down through the patient’s arms to perform a high-velocity, low-amplitude thrust (Figure 2). The only instruction provided concerning the segments to target were that the thrust had to be directed between T1-T4. The third technique (middle thoracic spine manipulation) was performed in the identical fashion as the upper thoracic technique except that the patient grasped the opposite shoulder with his/her hands (Figure 3). The only instruction provided relative to target segments with this technique was to direct the thrust between T5-T8. Immediately after performing a manipulation, the treating therapist recorded if a pop was heard. Regardless of the presence of a pop, the therapist again performed the identical manipulation technique. Therefore, each patient received 6 manipulations per treatment session. The operational definition of a pop was an audible sound heard by either the patient or therapist. Due to the complexities of assessing how many pops occurred[10] with one thrust technique, any pops (single or multiple) were recorded as one. Following the manipulation techniques, all patients were instructed in a CROM exercise (10 repetitions performed 3–4 times daily)[50] and advice for maintaining their usual activity within the limits of pain.

TABLE 2. Procedures used for cervical range of motion measurements

Test	Performance	Reliability ICC and 95% CI
Starting Position	Before taking any measurements, all patients were instructed to “sit upright” and to keep their eyes focused ”straight ahead.” Prior to movement testing, patients reported their current level of symptoms on a numeric pain rating scale and were instructed that these symptoms served as a baseline.	NA
Neck Flexion and Extension	For neck flexion, the inclinometer is placed on the top of the patient’s head aligned with the external auditory meatus and then zeroed. The patient is asked to flex the head forward as far as possible, bringing the chin to the chest. The amount of neck flexion is recorded from the inclinometer. For extension ROM, the inclinometer is positioned in the same manner, and the patient is asked to extend the neck backwards as far as possible. The amount of neck extension is recorded with the inclinometer.	Flexion: .75 (.50-.89)[38] Extension: .74 (.44-.88)[38]
Neck Side-Bending	The inclinometer was positioned in the frontal plane on the apex of the patient’s head in alignment with the external auditory meatus. To measure right side-bending, the patient was asked to move the right ear to the right shoulder. The amount of side-bending was recorded with the inclinometer. The opposite is performed to measure left side-bending. Care should be taken to avoid concomitant rotation or flexion with the side-bending movement.	Right: .66 (.33-.84)[38] Left: .69 (.40-.86)[38]
Neck Rotation	Rotation was measured with a universal goniometer. The patient was seated, looking directly forward with the neck in a neutral position. The fulcrum of the goniometer was placed over the top of the head with the stationary arm aligned with the acromion process, and the moveable arm bisecting the patient’s nose. The patient was asked to rotate in each direction as far as possible. Similar to extension, cervical rotation may produce dizziness or nausea in patients with VBI.	Right: .78 (.55-.90)[38] Left: .77 (.52-.90)[38]

ICC-intraclass correlation coefficient; CI-confidence interval; ROM-range of motion; VBI-vertebrobasilar insufficiency

Fig. 1.

Fig. 2.

The follow-up session occurred 2-4 days after the first session at which time each patient again completed the NDI and NPRS and CROM measurements were taken. In addition, at the follow-up examination, all patients completed the Global Rating of Change (GROC). The GROC is a 15-point global rating scale ranging from –7 ("a very great deal worse") to zero ("about the same") to +7 ("a very great deal

Fig. 3.

better")[51]. Intermittent descriptors of worsening or improving are assigned values from –1 to –6 and +1 to +6, respectively[52,53]. Jaeschke et al[51] reported that scores of +4 and +5 were indicative of moderate changes in patient status and scores of +6 and +7 indicated large changes in patient status.

Data Analysis

The number of pops as operationally defined in this study that occurred with each patient was tallied, and the mean and standard deviations were calculated. The relationship between the total number of pops (maximum of 6) and change scores for pain, disability, and CROM were examined using Pearson correlation coefficients. Since thrust procedures directed to the thoracic spine often result in a high percentage of audible pops[10], the number of times a thrust manipulation resulted in a pop occurring during the 6 techniques was recorded. Patients were then categorized as having experienced ≤3 or >3 pops. We wanted to establish a cut-off value that allowed the patient an equal opportunity to be in either group and hence selected a cut-off value of 3, since patients could logically experience between 0 and 6 pops. Key baseline demographic variables and scores on the self-report measures were compared between the two groups using independent *t*-tests for continuous data, and χ^2-tests of independence for categorical data (Table 3). The effects of the number of pops on pain, disability, and CROM were examined with a 2-way repeated-measures analysis of variance (ANOVA), with treatment group (≤3 or >3 pops) as the between-subjects variable and time (baseline and follow-up) as the within-subjects variable. Separate ANOVAs were performed with pain (NPRS), disability (NDI), and CROM as the dependent variables. For each ANOVA, the hypothesis of interest was the 2-way interaction (group x time).

An independent *t*-test was used to determine if a difference in GROC scores differed between patients experiencing ≤3 or >3 pops. Additionally, a χ^2-test and an odds ratio were calculated to determine if the number of pops that occurred were associated with substantial clinical improvement, which in this study was defined as GROC score of +5 or greater, i.e., "quite a bit better," "a great deal better," or a "very great deal better." Data analysis was performed using the SPSS Version 13.0 statistical software package (SPSS Inc, Chicago, IL).

Results

A total of 80 patients were enrolled in the study and 78 returned (98%) for the follow-up visit. Two subjects did not return after the first session for reasons unrelated to the study and were, therefore, not included in the analysis. The mean age was 42.0 (SD = 11.3) years, and the subjects had experienced an average of 80.0 (SD = 70.6) days of neck pain symptoms during the current episode. Baseline demographics for all subjects can be found in Table 3. The mean number of pops experienced was 3.8 (SD = 1.6). Pearson correlation coefficients examining the relationship between the number of pops and changes in pain, disability, and CROM can be found in Table 4. The only significant relationships occurred between the number of pops and changes in cervical side-bending right (r= –0.27), rotation right (r= –0.40), and rotation left (r= –0.34); however, these correlations were negative indicating that a greater number of pops experienced was related to smaller change scores for these measures.

A total of 21 patients experienced ≤3 pops and 51 experienced >3 pops (Figure 4). Baseline characteristics between the groups were similar for all variables including pain, disability, and CROM (P>0.05) (Table 3). The mean time to follow-up for the group experiencing ≤ 3 pops was 2.3 (SD = 0.86) days and was 2.3 (SD = 0.20) days for the group experiencing >3 pops (P= 0.82). The overall 2-way group x time interaction for the repeated-measures ANOVA was not statistically significant for disability (P= 0.66) or pain (P= 0.41). The between-group differences for improvements in disability measured on the NDI were 0.38 (95% CI, -7.5, 6.8); with regard to pain as measured on the NPRS, they were 0.33 (95% CI, -1.2, .78) (Table 5). There was no significant group x time interaction for any of the CROM measurements (P>0.05). Change scores as well as between-group differences for CROM measurements can be found in Table 5. The results demonstrated that the between-group differences for

TABLE 3. Demographics, baseline self-report variables, and baseline characteristics of subjects.

Variable		All Subjects (n=78)	≤ 3 pops (n=27)	> 3 pops (n=51)	Significance
Age, mean (SD)		42.0 (11.3)	43.1 (12.1)	41.3 (10.9)	.52[b]
Gender: Female n (%)		53 (68%)	18 (67%)	35 (68%)	.79[a]
Duration of symptoms (days), mean (SD)		80 (70.6)	81.9 (80.0)	79.0 (66.0)	.87[b]
NPRS, mean (SD)		4.7 (1.8)	4.5 (1.8)	4.8 (1.8)	.47[b]
NDI, mean (SD)		34.9 (10.1)	35.6 (12.6)	34.5 (8.7)	.65[b]
FABQPA, mean (SD)		12.6 (4.1)	12.9 (4.6)	12.5 (3.8)	.73[b]
FABQW, mean (SD)		13.1 (10.1)	11.8 (12.2)	13.7 (8.9)	.43[b]
Symptoms distal to the shoulder, n (%)		35 (45%)	11 (41%)	24 (47%)	.37[a]
Mode of onset: Traumatic, n (%)		32 (41%)	13 (48%)	19 (37%)	.47[a]
Prior history of neck pain, n(%)		26 (33%)	11 (41%)	15 (29%)	.22[a]
Cervical range of motion: mean (SD)					
	Flexion	42.5 (11.8)	42.2 (11.9)	42.7 (11.9)	.87[b]
	Extension	33.9 (12.6)	31.5 (12.8)	35.0 (12.4)	.24[b]
	Side bend right	31.4 (12.9)	28.1 (9.2)	33.2 (14.2)	.10[b]
	Side bend left	32.9 (14.8)	30.0 (10.2)	34.3 (16.6)	.21[b]
	Rotation right	60.6 (12.0)	58.6 (14.2)	61.8 (10.6)	.26[b]
	Rotation left	61.2 (12.2)	60.1 (11.2)	61.8 (12.8)	.56[b]

NPRS = Numeric Pain Rating Scale; NDI = Neck Disability Index; FABQPA = Fear-Avoidance Beliefs Physical Activity Subscale; FABQW= Fear-Avoidance Beliefs Work Subscale; [a] Chi-square tests; [b] Independent samples *t*-tests

TABLE 4. Pearson correlational coefficients examining the relationships between the number of pops and change scores for pain, disability, and CROM measurements.

Change Scores	Pearson Correlation Coefficient with the Number of Pops Experienced
NPRS	-.005
NDI	.17
Cervical flexion	.032
Cervical extension	.064
Cervical side-bending right	-.27
Cervical side-bending left	-.99
Cervical rotation right	-.40**
Cervical rotation left	-.34

NPRS = Numeric Pain Rating Scale; NDI = Neck Disability Index; ** = significant at P<0.01

the NDI did not surpass the MDC of 10 percentage points[29], and the between-group differences for the NPRS did nor surpass the MCID of a 2-point change[33,34].

No significant difference (P= 0.14) in follow-up GROC scores existed between groups with the mean score of a 2.4 (SD = 2.3) in the group receiving ≤3 pops and a mean score of 2.2 (SD = 2.6) for the group receiving >3 pops. Of the patients who experienced ≤3 pops 7 (33%) experienced a successful outcome based on achieving at least a +5 on the GROC, while 16 (31%) in the group experiencing >3 pops met this threshold (P= 0.79). The odds ratio for patients experiencing a successful outcome was 1.3 (95% CI: 0.46, 3.7) in favor of the group that experienced ≤3 pops. This suggests that patients who experienced ≤3 pops were 1.3 times more likely to experience a successful outcome than the group that experienced >3 pops.

Discussion

It has traditionally been thought that a pop must accompany a thrust spinal manipulation to assure success of the particu-

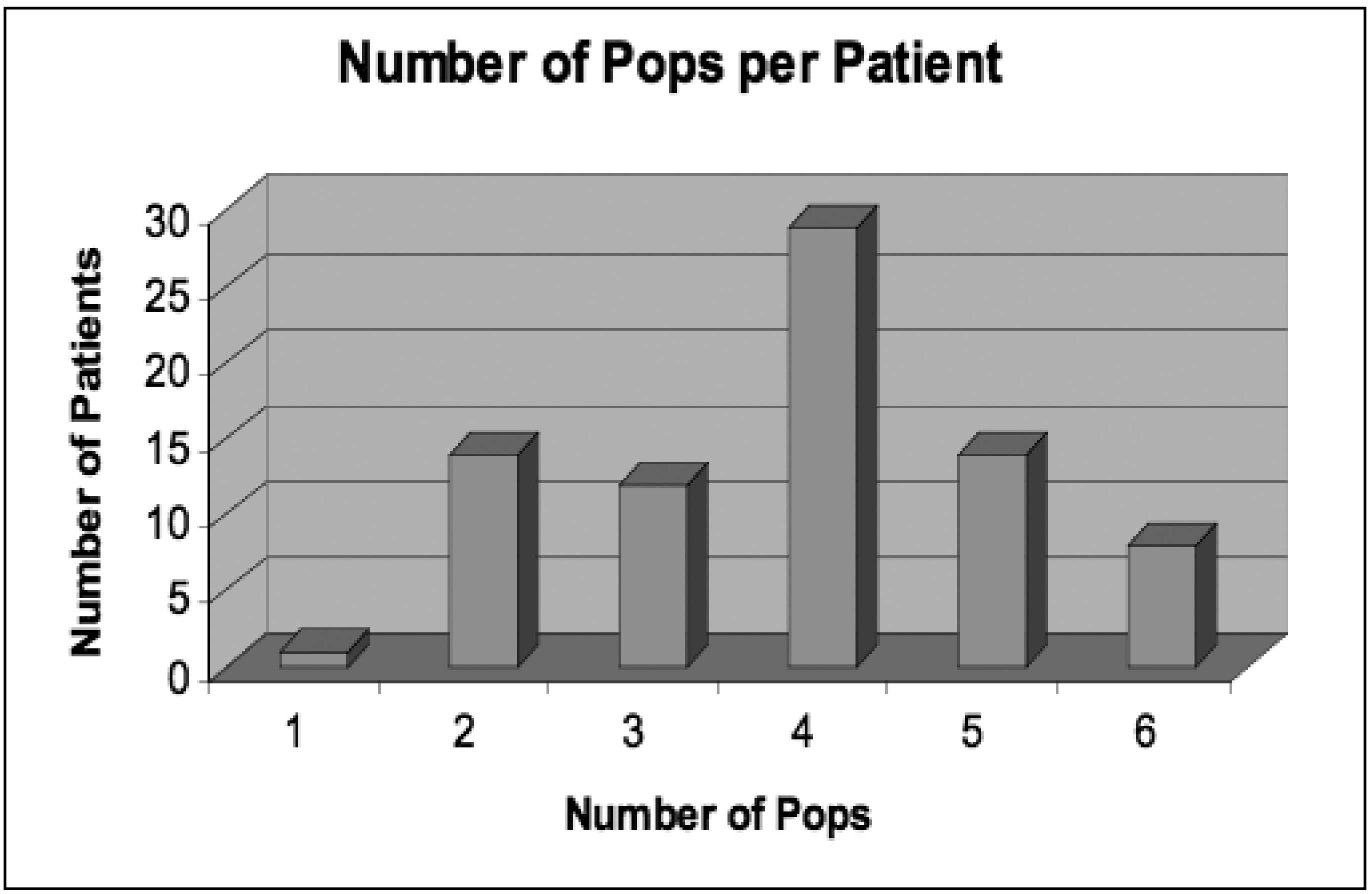

Figure 4.

TABLE 5. Change scores and between-group differences for pain, disability, and cervical range of motion.

Variable		≤ 3 pops (n=27)	> 3 pops (n=51)	Between-group differences (95% CI)
NPRS, mean (SD)		1.6 (1.7)	1.8 (2.8)	.33 (-1.2, .78)
NDI percentage points: mean (SD)		13.8 (8.8)	14.2 (12.7)	.38 (-7.5, 6.8)
Cervical Range of Motion: mean (SD)				
	Flexion	2.8 (8.4)	7.2 (13.9)	-4.3 (-10.2, 1.6)
	Extension	12.5 (19.3)	17.2 (16.4)	-4.7 (-13.2, 3.7)
	Side bend right	6.8 (9.4)	3.0 (9.9)	3.8 (-.94, 8.5)
	Side bend left	4.2 (8.2)	2.4 (8.5)	1.7 (-2.3, 5.8)
	Rotation right	11.2 (12.7)	6.5 (11.6)	4.7 (-1.2, 10.7)
	Rotation left	11.8 (13.2)	6.2 (11.9)	5.6 (-.34, 11.6)

NPRS = Numeric Pain Rating Scale; NDI = Neck Disability Index

lar technique selected despite a lack of evidence suggesting that this is the case[10]. However, the results of the current analysis provide preliminary evidence that no statistically significant relationship existed between the number of audible pops occurring during thoracic thrust manipulation in patients with mechanical neck pain and improvements in pain, disability, or CROM. When dichotomized into two groups experiencing either ≤3 or >3 pops, between-group differences did not exceed the MDC or MCID on the NDI and NPRS, respectively, indicating the absence of true and clinically meaningful between-group differences in these outcome measures. In fact, the number of pops was significantly inversely correlated with changes in cervical side-bending and rotation range of motion, which is counterintuitive to conventional wisdom. Additionally, our findings demonstrated that although the odds ratio was small and not clinically meaningful, it favored the group experiencing ≤3 pops. This further enhances the likelihood that the audible pop is not associated with a successful outcome in this particular group of patients.

The result of the current analysis is similar to the findings of Flynn, Fritz, et al[12], who demonstrated that no relationship existed between the audible pop and outcomes in patients with low back pain who received a lumbopelvic thrust manipulation technique in the short term. Flynn, Childs, et al[13] also demonstrated that there appears to exist no longer-term benefit associated with the audible pop. The result of the current study did not provide long-term data, but based on our findings, it appears that the pop may not be associated with improved outcomes regardless of the area of the spine treated.

It is commonly thought that the audible pop associated with thrust manipulation is related to separation of the zygapophyseal joint surfaces[54]. In the current study, we did not attempt to identify if the pop was emanating from the segment targeted with the thrust manipulation. However, attempting to isolate the pop to the target segment may not be realistic. It has been demonstrated that the effects of thoracic spine thrust manipulation are not localized to the target segment. In fact, Ross et al[10] showed that with thrust manipulation to the lumbar and thoracic spine, the pop originated from the target segment only 53% of the time[10]. In addition, in this study the majority of the manipulations resulted in noise at multiple segments from which these authors concluded that manipulation was not segment-specific[10]. This data along with the result of our study suggest that the sounds associated with thrust manipulation techniques not only lack specificity but also that the pop may not be not useful in guiding decision-making regarding the success of a procedure. Perhaps identifying the proper subgroup who will respond best to thrust manipulation techniques is more relevant than selecting a particular technique or using the pop to guide clinical decision-making[44]. Clinicians should focus on patient-centered outcomes rather than the presence or absence of a pop when determining the benefits of thrust manipulation[11].

We acknowledge that the major limitation with this study lies in the operational definition we chose for recording presence or absence of an audible pop. When performing thrust manipulation directed at the thoracic spine, often multiple pops will occur with each technique[10]. However, we felt it was not reasonable to ask clinicians to count how many pops exactly occurred during one particular technique but rather if any audible pop occurred. This is reflected in the operational definition we chose in this study for the audible pop that is similar to the operational definition used in two previous studies done on this topic in patients with mechanical low-back pain[12,13]. It has been documented that a refractory period exists following an audible pop in the metacarpophalangeal joint whereby the joint will not pop again until sufficient re-absorption of gases has occurred within the joint[55]. Hence, assuming this phenomenon also applies to the thoracic spine, we can imagine a scenario where multiple joints could have popped during a single thrust procedure rendering the joints in a refractory period and, therefore, unable to pop during the following thrust manipulation. Therefore, it is possible that patients who were classified by the researchers as having experienced ≤3 pops might have actually had more joints pop than those who were categorized as having experienced >3 pops. This increased number of cavitations might in theory result in a greater neurophysiological effect and subsequently a greater impact on our outcome measures. However, this argument may apply equally to the earlier studies, because research has shown that manipulations directed at the sacroiliac joint and lumbar spine also may result in multiple cavitations per thrust technique applied; for example, Beffa and Matthews[56] reported 65 cavitations with the 30 thrust manipulations applied in their study. Future studies should investigate whether the total number of pops occurring has an impact on patient outcomes.

Another limitation is the failure to collect long-term follow-up data. While no differences between groups were noted at the short-term follow-up period, we cannot be certain that this persisted at a time period greater than the 2–4 days. Additionally, we used one specific set of spinal manipulation techniques[7]. It is possible that different manipulation techniques could result in different responses. While we cannot make direct generalizations about the association of a pop and the outcomes associated with other thrust manipulation techniques in patients with neck pain, recent studies have suggested that the specific technique used might not be as critical in the decision-making process as once speculated[44,57]. In addition, we did not utilize cervical spine thrust procedures in the current study so direct inferences between a pop and outcomes associated with cervical spine manipulation cannot be ascertained.

Conclusion

This study provides preliminary evidence that there is little to no relationship between the audible pop frequently noted during spinal manipulation and improvement in pain, cervical ROM, and disability in the short term in individuals with mechanical neck pain receiving thoracic spine thrust manipulation. Furthermore, the number of occurrences of a pop did not improve the odds of a dramatic improvement following spinal manipulation. Therefore, practitioners who use these techniques should be cautious in attributing any therapeutic benefit to the audible pop. However, further research is needed to examine the relationship between the actual number of pops that occur and the outcome measures collected in this study rather than the number of audible pops as operationally defined in this study.

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